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Title:	Support Documentation for PIC Simulations on TWTs that Utilize High-e Dielectrics
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Support Documentation for PIC Simulations on TWTs that Utilize High-ε Dielectrics

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Introduction

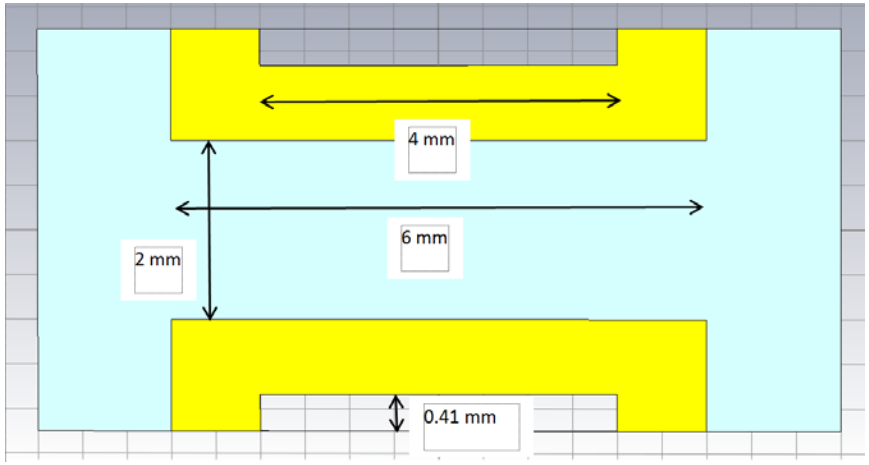
- **PIC simulations for a LANL LDRD project have shown issues with some of the results**
  - Numerical instabilities/noise
  - Prediction of synchronous energy
- **Benchmarking efforts have started**
  - Published NRL structure with similar characteristics was calculated and results were confirmed
  - Collaboration with the EE department at UNM in Albuquerque (Edl Shamiloglu) for calculation with another well benchmarked software package

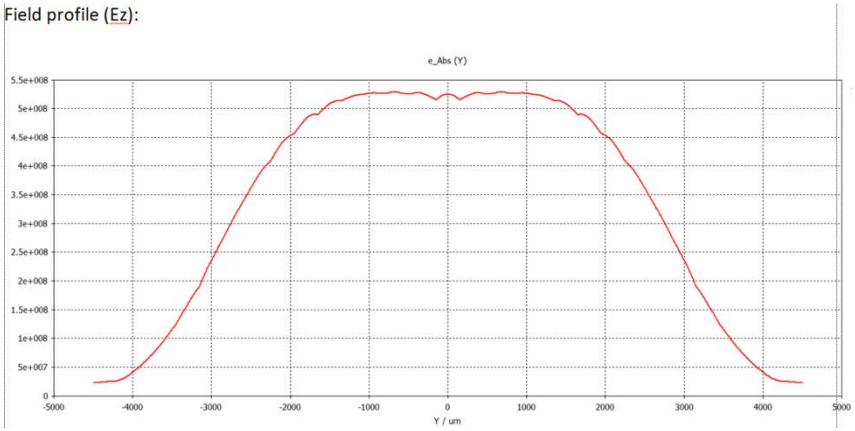
Outline

- Basic RF structure and properties
- RF structure and RF coupler system
- PIC model w/o coupler
- Some PIC simulation results (CST-PS 2017)
- Questions
- Simulations of a simpler, circular TWT published by NRL

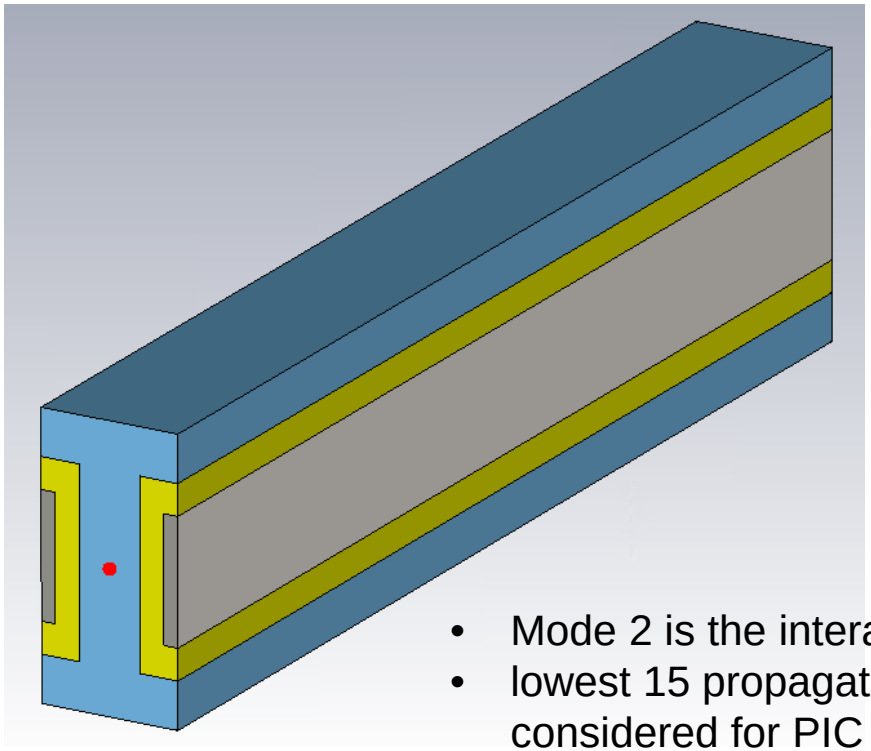
Basic RF structure and properties

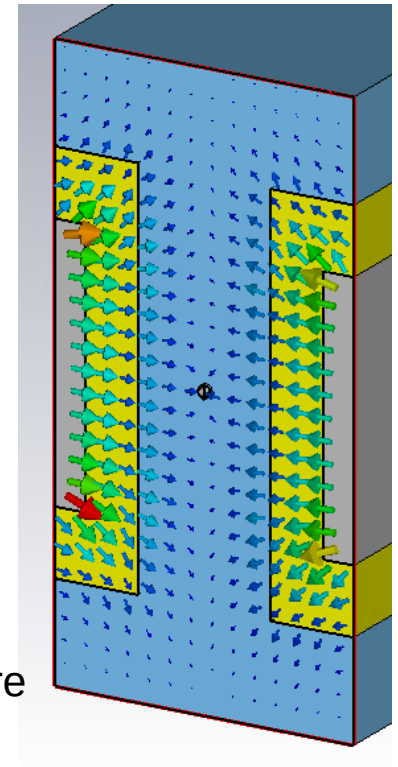
- Operation is at the center of Ka-band (33.25 GHz)
- One of the challenges of the structure is that the cross-section is highly over-moded
- Properties of the dielectric: ε_r=20 , tan δ=0.001
- Nominal velocity matches to 20 keV beam





PIC model w/o coupler

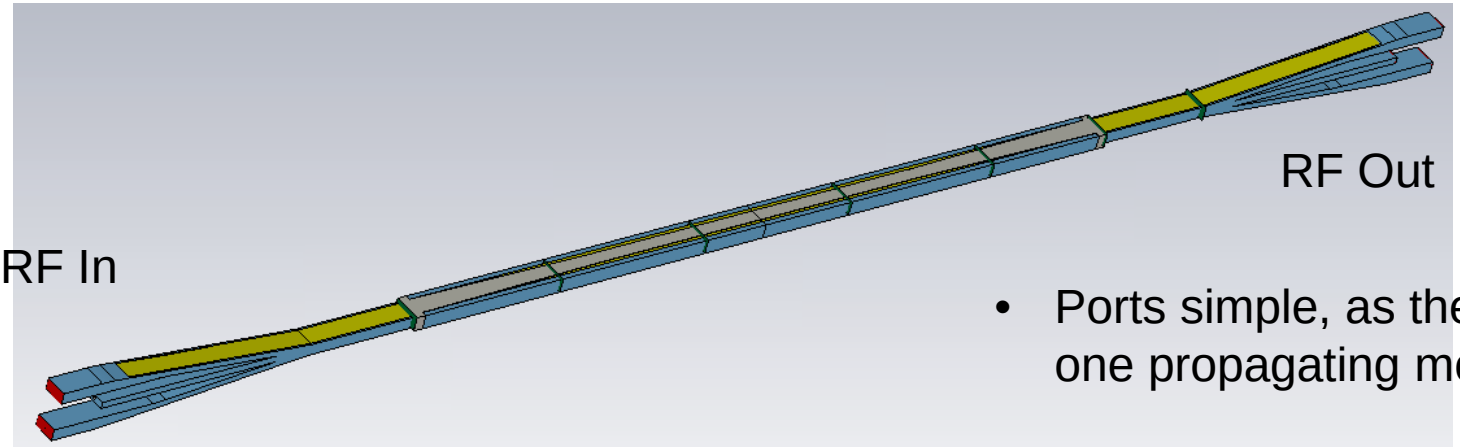




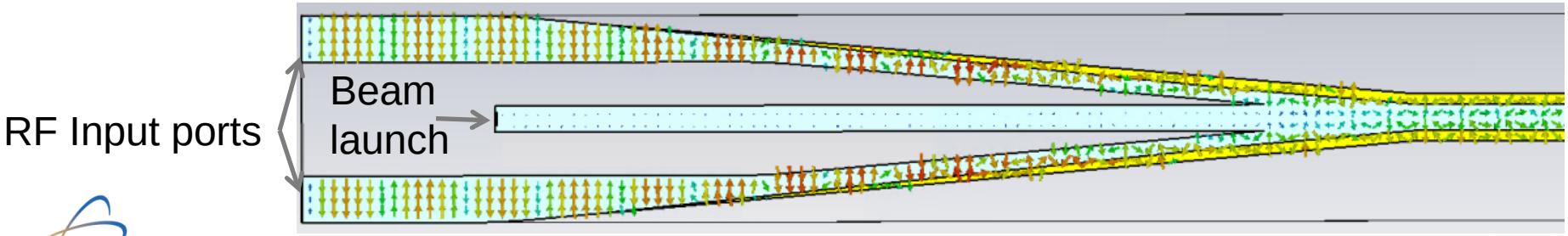
- Mode 2 is the interaction mode
- lowest 15 propagating modes are considered for PIC
- There are more than 100 propagating modes
- Sims use a mix of port modes and a Muir (damping) boundary

RF structure and RF coupler system

While this is not the final coupler/tube configuration – this one is more suitable for the PIC simulations. It has the proper mode generation from to empty ports that are 180 degrees out of phase.

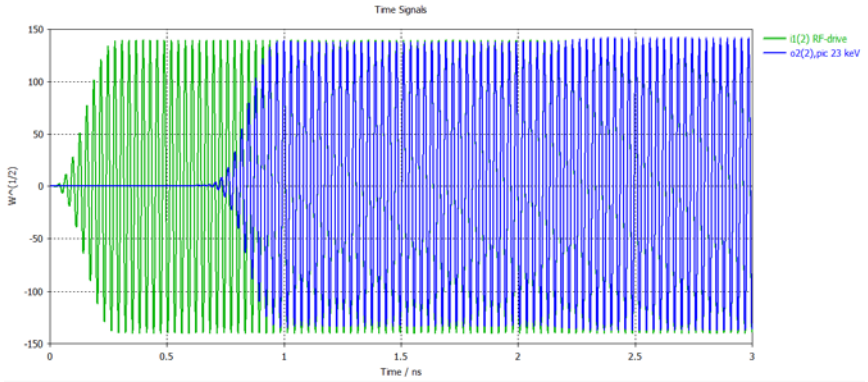


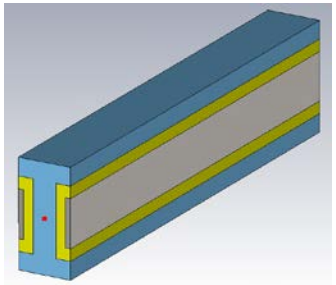
- Ports simple, as there is only one propagating mode



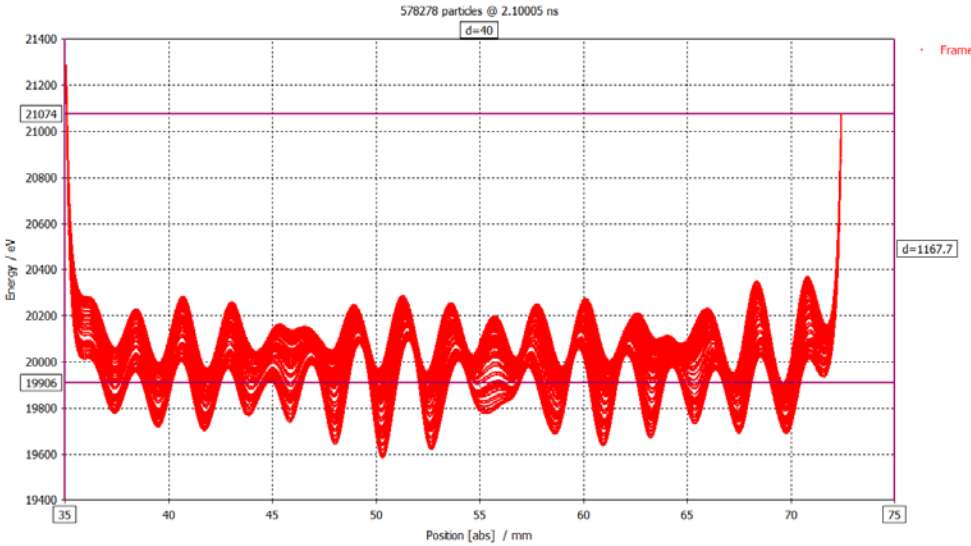
Some PIC simulation results (CST-PS 2017)

- **Simulations for the interaction structure alone show no gain**
  - RF input (green) and RF output show the same amplitude over a wide range of beam energies (20-25 keV)



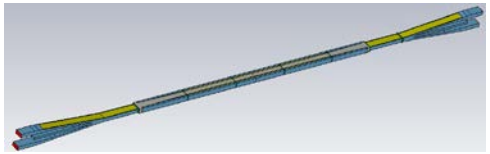


- **and unphysical potential depression (> 1 keV)**
  - Snapshot of energy along structure

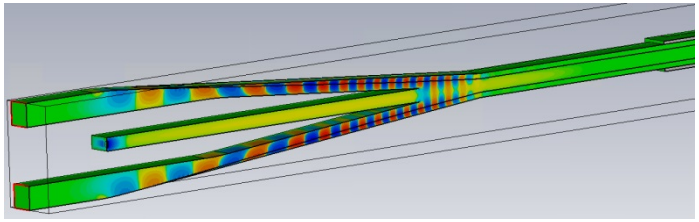


Some PIC simulation results (CST-PS 2017)

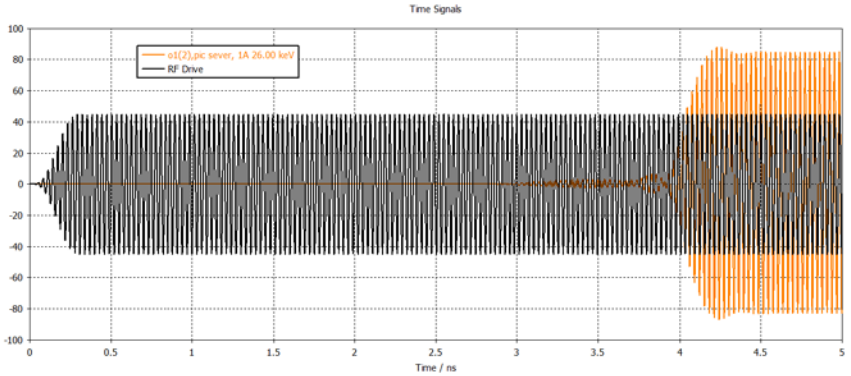
- **Simulations for full structure show gain, but at much higher energy than expected**



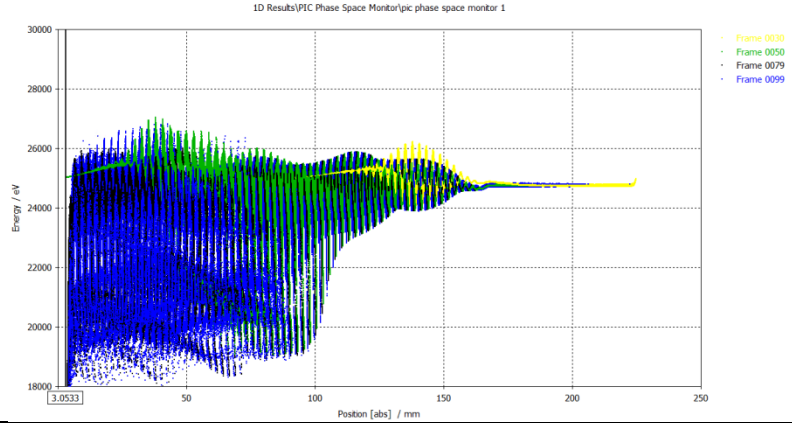
- **Simulation details:**
  - RF fields need 1 ns to build up – beam start delayed to arrive in structure when RF is at full amplitude



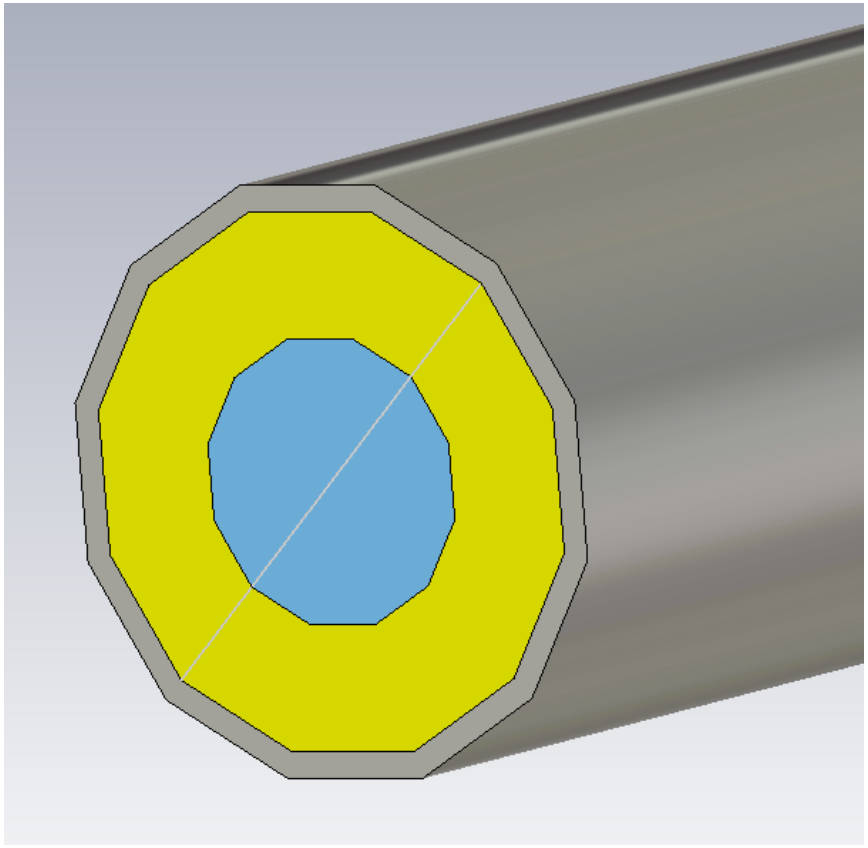
- **RF input (black) and output at 26 keV (best gain)**



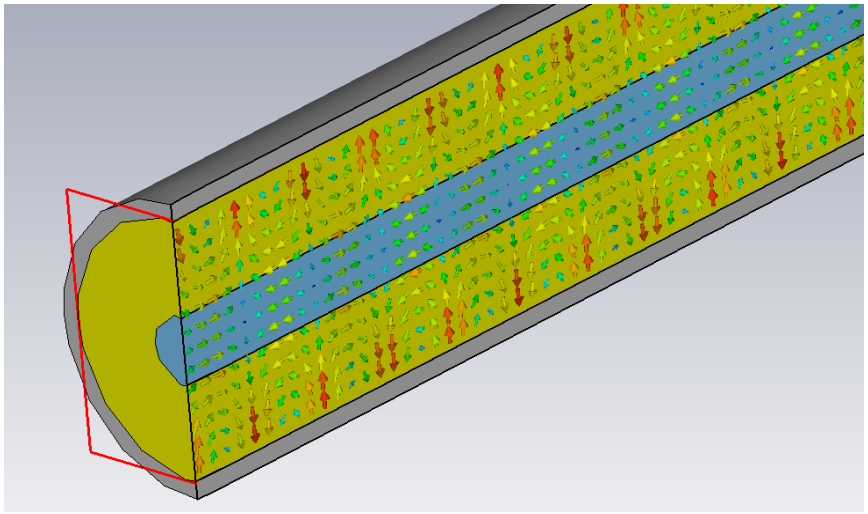
- **Snapshot of energy shows transfer to field**



Simulations of a simpler, circular TWT published by NRL



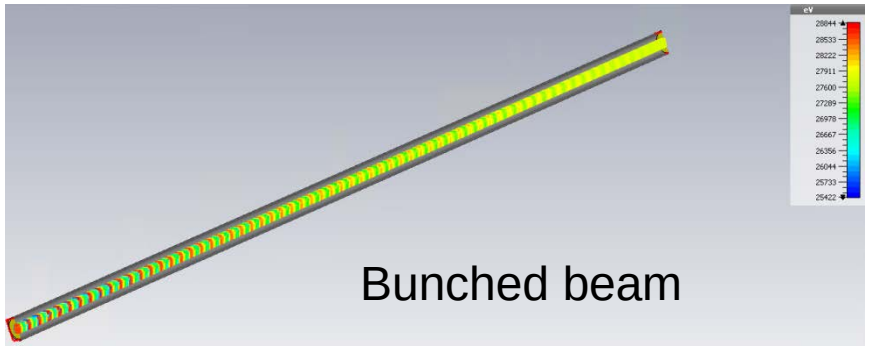
Cross-section for solid beam

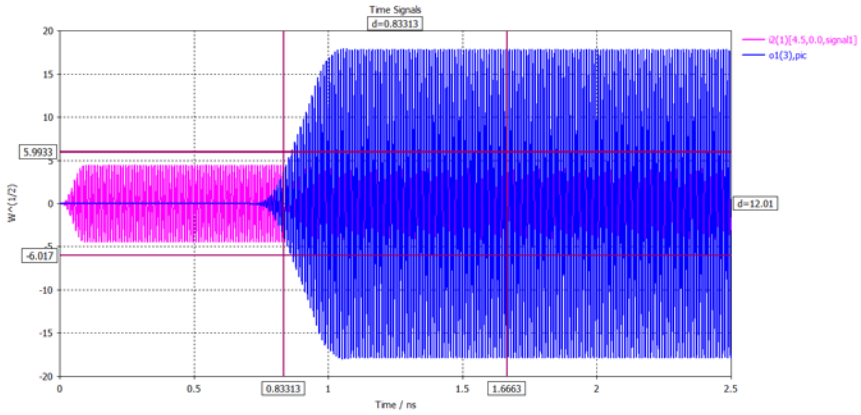


Interaction mode without beam

Nominal interaction at 25.75 keV

Simulations of a simpler, circular TWT published by NRL





RF input (pink) and RF output shows gain

Beam energy [keV]	Power in [W]	Power out [W]	Gain [dB]
25.75	20	-	
26.00	20	-	
26.25	20		
26.50	20	23.7	0.74
26.75 (4% high)	20	73	5.6
nominal	**10**	**120**	**10**
27.75 (8% high)	20	306	11.9

Comparison of Typical Parameters

	LANL	NRL	Comments
Frequency	33.25	94	GHz
Energy	20	25.75	keV
Dielectric (ε)	20	13.5	
Tan δ	0.001	N/A	Not used
Port modes	15	5	considered
Interaction discrepancy	~25%	~ 5%	

Questions

- **CST cannot find gain in the LANL structure without coupler**
  - Why?
  - ICEPIC result
- **CST finds gain in structure with coupler, but the interaction energy is wrong**
  - Why?
  - ICEPIC result
- **CST does the NRL structure reasonably**
  - Why? Difference to LANL structure?
  - ICEPIC result